The Ent Dynamic Global Terrestrial Ecosystem Model (Ent DGTEM):

What does it do, how does it do it, and what can it do for you

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NASA-GISS, Lunch Seminar, October 8, 2008

COMMUNITY GOALS

SCIENTIFIC COMMUNITY:

ENT will be a standalone set of modules that can be used by the climate modeling community to couple with land hydrology models and atmospheric GCMs

NASA:

- Span the goals of Goddard,GISS, and NAI
- Use with:
  - GMAO modeling system to allow assimilation of satellite data
  - GISS GCM for long-term climate studies
  - Virtual Planetary Laboratory extrasolar planet models

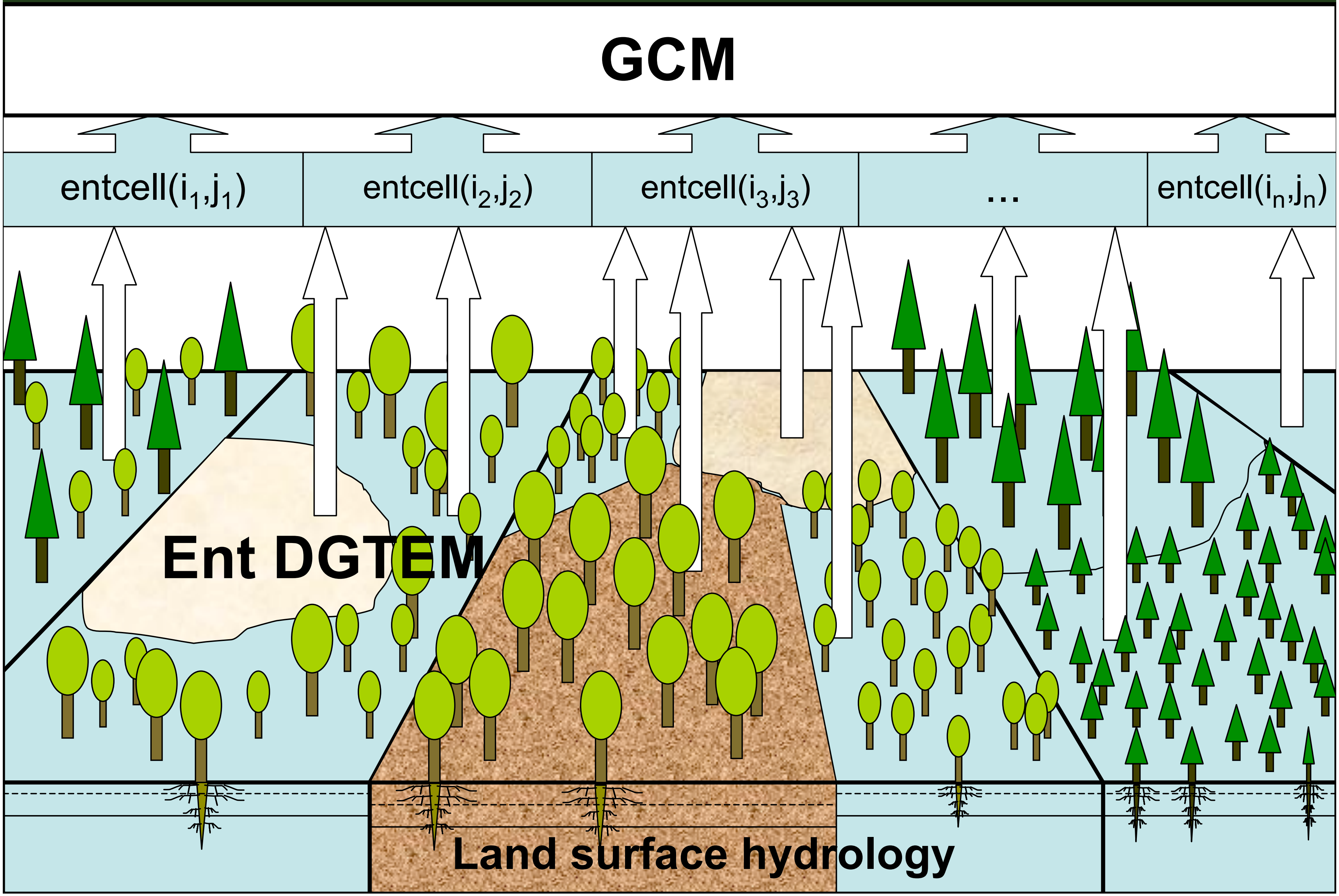
SCIENTIFIC GOALS:

Outputs:
* Fast time scale fluxes of water, carbon, *nitrogen* and energy between the land surface and the atmosphere
* Diurnal surface fluxes
* Seasonal and inter-annual vegetation growth and soil biogeochemistry
* Decadal to century scale change in vegetation structure and soil C *and N*.

Approach:
* Radiative transfer, biophysics, biogeochemistry, and ecological dynamics integrated in a consistent, prognostic, process-based manner
* Unique features: mixed vegetation canopies, *coupled C and N cycles*, *leaf albedo function of photosynthetic N*,
* Computationally efficient but biologically realistic
* Suitable for two-way coupling and parallel computing in GCMs

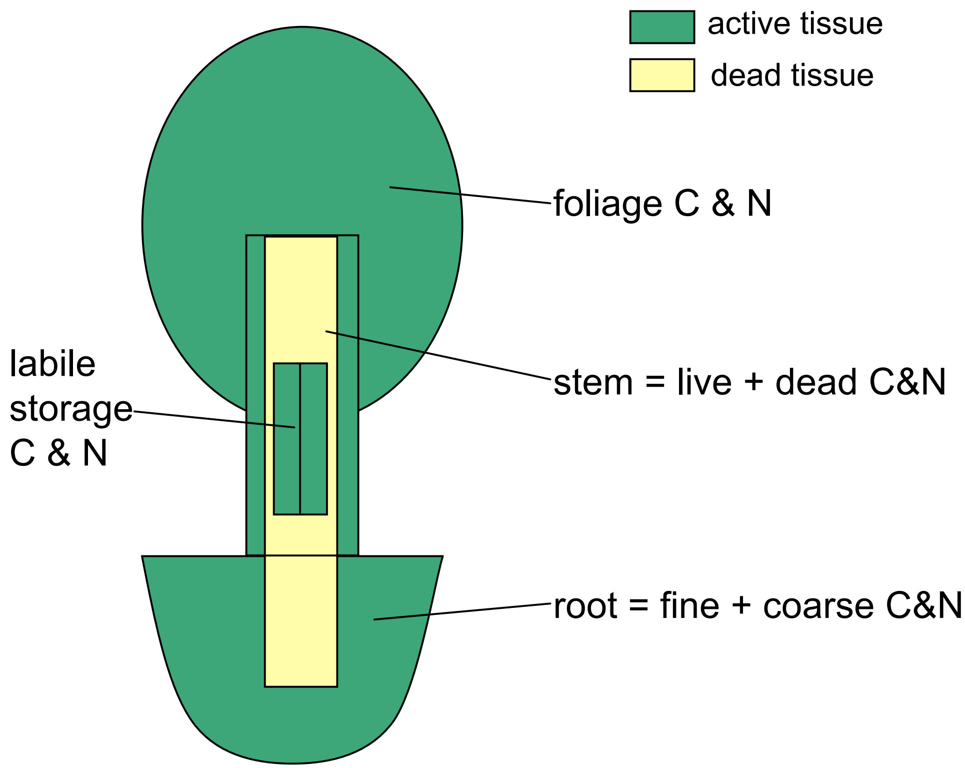
Research questions:
* seasonal weather evolution
* vegetation phenology
* the carbon budget
* climate variability
* paleoclimate
* global change scenarios
* vegetation-climate feedbacks
* astronomical biosignatures

Ent subgrid heterogeneity and mixed canopies



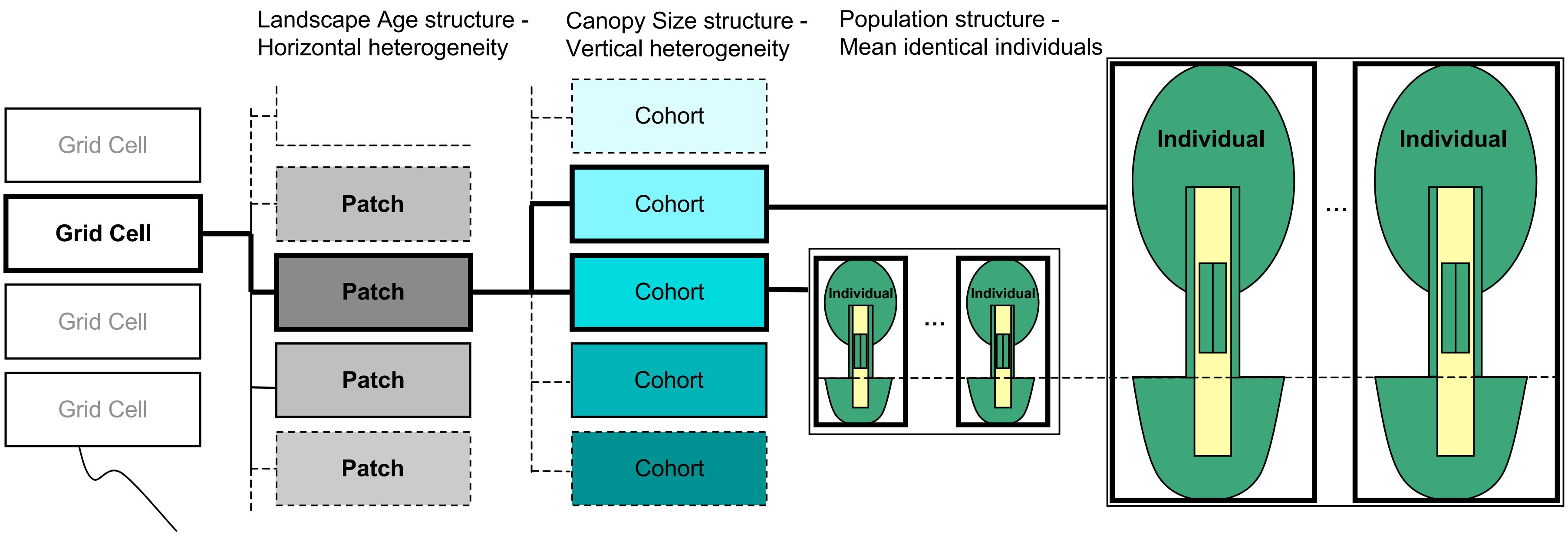
Individual tree: C & N pools

Ellipsoid crowns for canopy radiative transfer

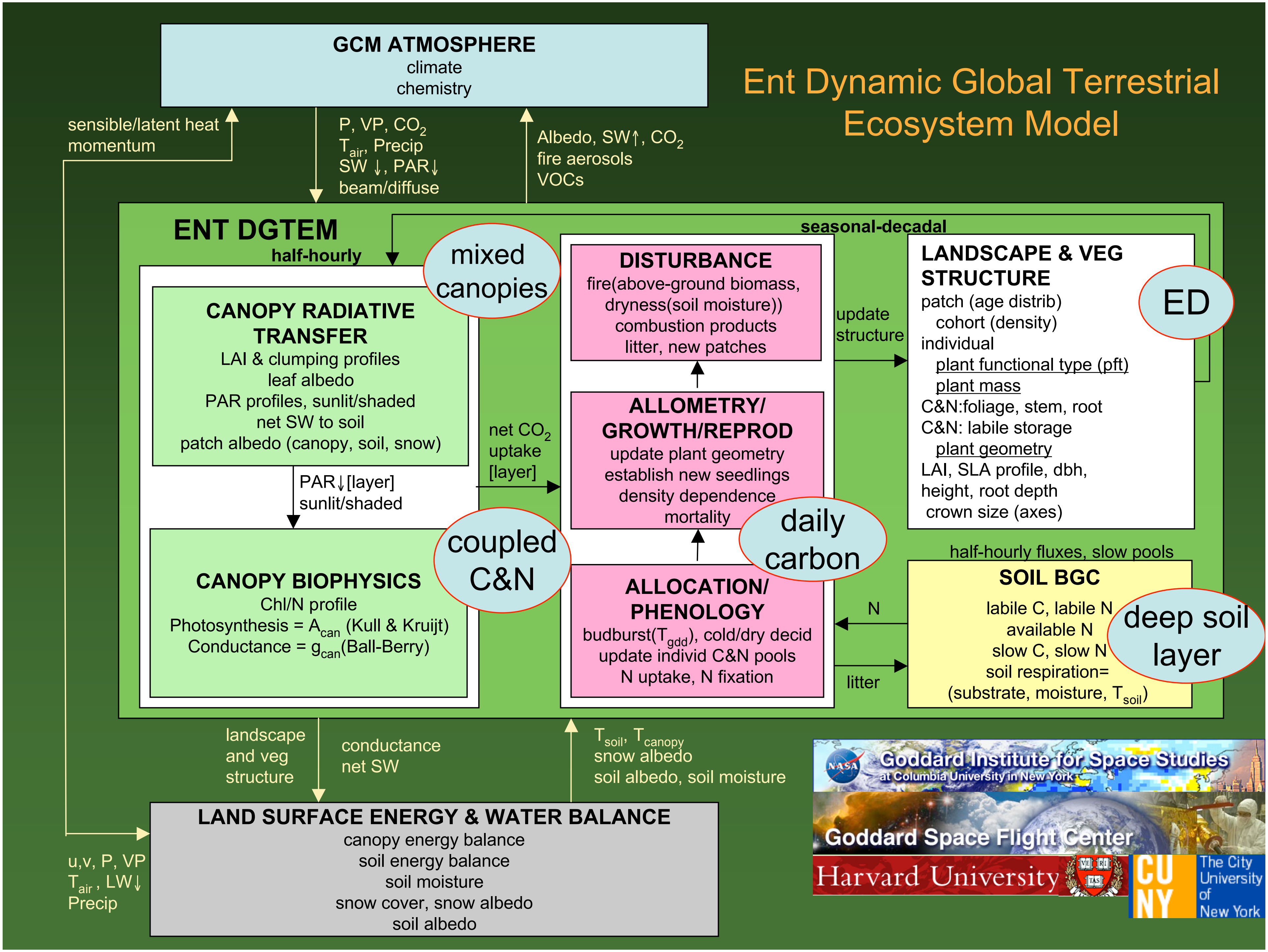


Structured ecosystem model:

- discretization of size and age -structured partial differential equations



Grid cell or
Catchment zone


Ent Dynamic Global Terrestrial Ecosystem Model
GCM ATMOSPHERE
climate
chemistry
sensible/latent heat
momentum
P, VP, CO_2
T_{air}, Precip
SW ↓, PAR↓
beam/diffuse
Albedo, SW↑, CO_2
fire aerosols
VOCs
ENT DGTEM
half-hourly
seasonal-decadal
mixed canopies
CANOPY RADIATIVE TRANSFER
LAI & clumping profiles
leaf albedo
PAR profiles, sunlit/shaded
net SW to soil
patch albedo (canopy, soil, snow)
PAR↓[layer]
sunlit/shaded
CANOPY BIOPHYSICS
Chl/N profile
Photosynthesis = A_{can} (Kull & Kruijt)
Conductance = g_{can}(Ball-Berry)
coupled C&N
net CO_2
uptake
[layer]
DISTURBANCE
fire(above-ground biomass,
dryness(soil moisture))
combustion products
litter, new patches
ALLOMETRY/
GROWTH/REPROD
update plant geometry
establish new seedlings
density dependence
mortality
daily carbon
ALLOCATION/
PHENOLOGY
budburst(T_{gdd}), cold/dry decid
update individ C&N pools
N uptake, N fixation
update
structure
LANDSCAPE & VEG STRUCTURE
patch (age distrib)
cohort (density)
individual
plant functional type (pft)
plant mass
C&N:foliage, stem, root
C&N: labile storage
plant geometry
LAI, SLA profile, dbh,
height, root depth
crown size (axes)
ED
half-hourly fluxes, slow pools
SOIL BGC
labile C, labile N
available N
slow C, slow N
soil respiration=
(substrate, moisture, T_{soil})
deep soil layer
N
litter
landscape
and veg
structure
conductance
net SW
T_{soil}, T_{canopy}
snow albedo
soil albedo, soil moisture
LAND SURFACE ENERGY & WATER BALANCE
canopy energy balance
soil energy balance
soil moisture
snow cover, snow albedo
soil albedo
u,v, P, VP
T_{air} , LW↓
Precip
Goddard Institute for Space Studies
at Columbia University in New York
Goddard Space Flight Center
Harvard University
CU NY
The City University of New York

Ent Special Features

- Canopy radiative transfer:
  * Foliage clumping derived from Geometric-Optical Radiative Transfer model (GORT, Ni, et.al., 1999)
- Canopy biophysics: Two schemes
  * Kull & Kruijt photosynthesis (1998) and Friend & Kiang canopy conductance (2005)
  * Farquhar-von Caemmer photosynthesis and Ball-Berry conductance of Collatz, et.al, (1991) and Collatz, et.al, (1992)
- Growth/allocation/allometry:
  - Daily updates
  - Consistent with ellipsoid crowns of radiative transfer scheme
  - Phenology (seasonality) includes tropical radiation seasonality, boreal cold hardening of photosynthetic capacity
- Ecological dynamics:
  - Disturbed patch-age and vegetation size-structured ensemble scheme of Moorcroft, et.al. (2001)
  - *Fire (coming Spring 2009)*

Ent “Core” Plant Functional Types (PFTs):

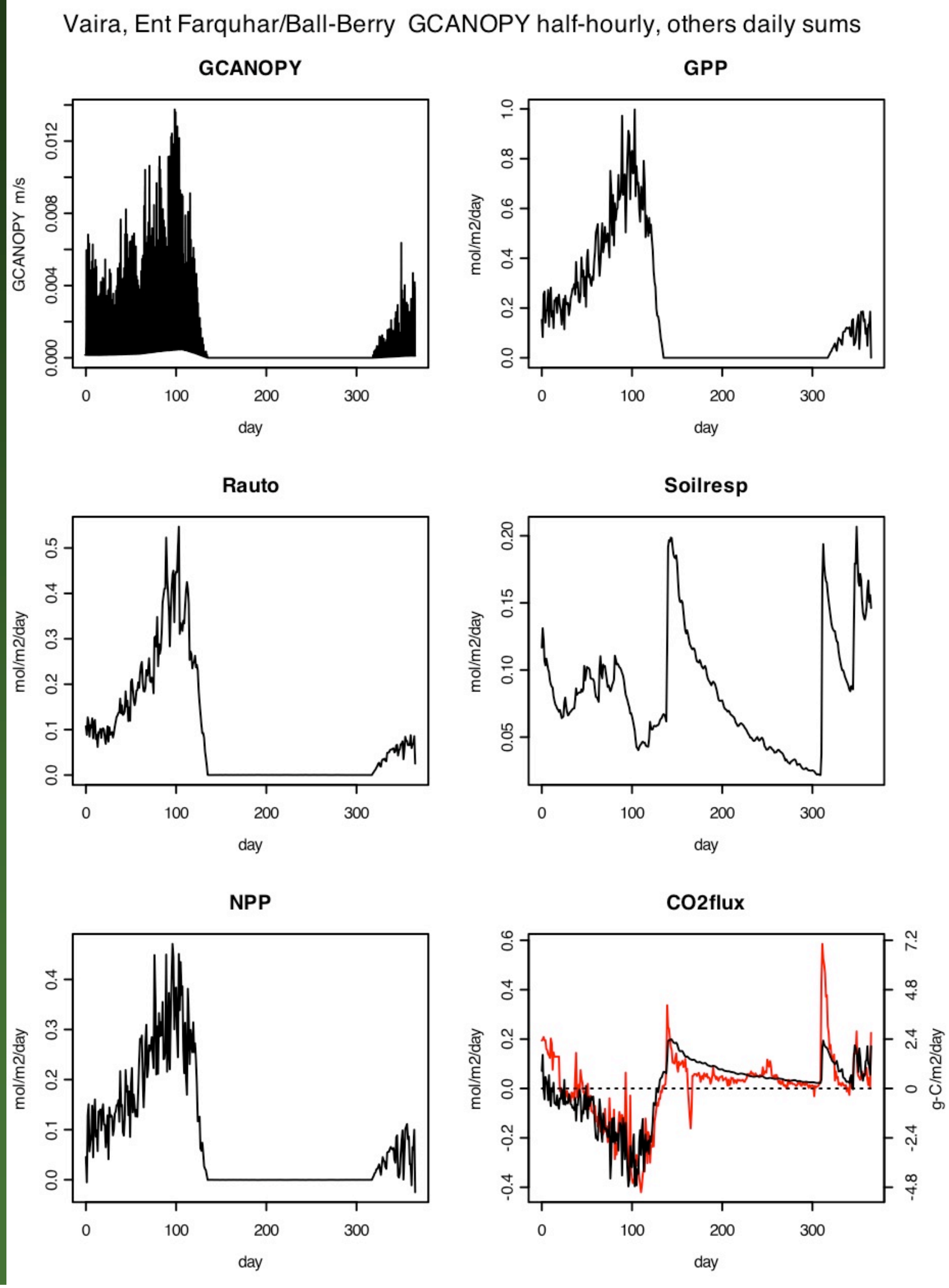
1-2: evergreen broadleaf, early and late successional*
3-4: evergreen needleleaf, early and late successional*
5-6: cold deciduous broadleaf, early and late successional
7: drought deciduous broadleaf
8: deciduous needleleaf
9: cold adapted shrub
10: arid adapted shrub
11: C3 grass - perennial
12: C4 grass
13: C3 grass - annual
14: arctic C3 grass
15: C4 crops - herbaceous
16: crops - woody broadleaf

*Based on Reich, et.al. (1999) data on
specific leaf area/nitrogen/leaf longevity relations.

Diagnostics/ outputs from Ent

LAI
Canopy conductance
CO_2 flux components
C stocks
Albedo
Vegetation cover types

Eventually:
VOCs
N fluxes and stocks
Fire emissions
Roughness length
Canopy heat capacity



Progress to date

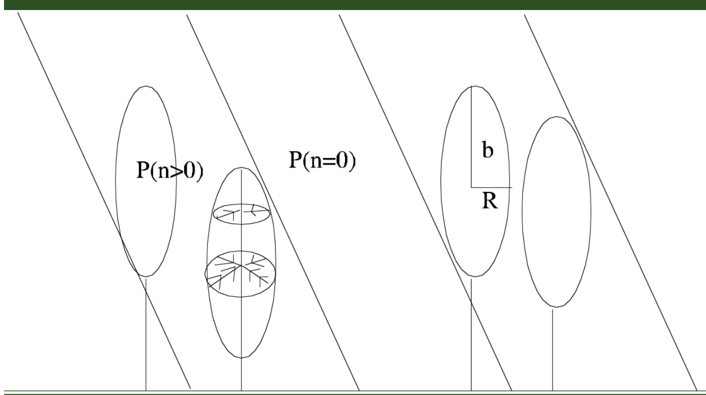
	Process	Summary	Site tests Fluxnet other	Global off-line	Coupled GISS GCM (prescr. CO2)	Coupled GMAO GCM (prescr. CO2)	Coupled GISS GCM (interactive CO2)	Future Work
Level 0:	Canopy radiative transfer	· Vertical light profiles with clumped foliage · Albedo	· Vertical light profiles many sites · Albedo · November: coupling to biophysics	MODIS - January GISS GHY - January	Jan 2009	Jan 2009	Jan 2009	Testing of EGVS-LIDAR
Level 1:	Biophysics	· Photosynthesis · Autotrophic respiration · Conductance of water vapor	· Boreal pine, temperate broadleaf deciduous, C3 annual grass, oak savnna · tropical rainforest, C4 grass (in progress)	GSWP2 1985-1996 testing	In progress	In progress	· In progress · AR5 runs start: Jan 2009	
Level 1:	Soil biogeo-chemistry	· **Soil respiration** · Soil carbon storage	· Same sites as biophysics	GSWP2 1985-1996	In progress	N/A	· In progress · AR5 runs start: Jan 2009	
Level 2:	Phenology/ allocation	· Timing of leafout and senescence · Allocation of carbon to foliage, stems, roots, reproduction	· Same sites as biophysics	Nov 2008	Jan 2009	TBA	March 2009 · AR5 runs? (unlikely)	
Level 3:	Patch dynamics	· Mortality, establishment, fire.	· TBA May 2009	*Oct 2009*	*June-Oct. 2010*	TBA	*June-Oct. 2010*	
Veg data	Land cover/use	· Construct Ent global vegetation structure (EGVS) dataset	Ent 16 PFT cover from MODIS cover + Matthews height in progress	Nov 2008			· AR5 runs start: Jan 2009	Update with LIDAR data

CO_2 fluxes

LAI

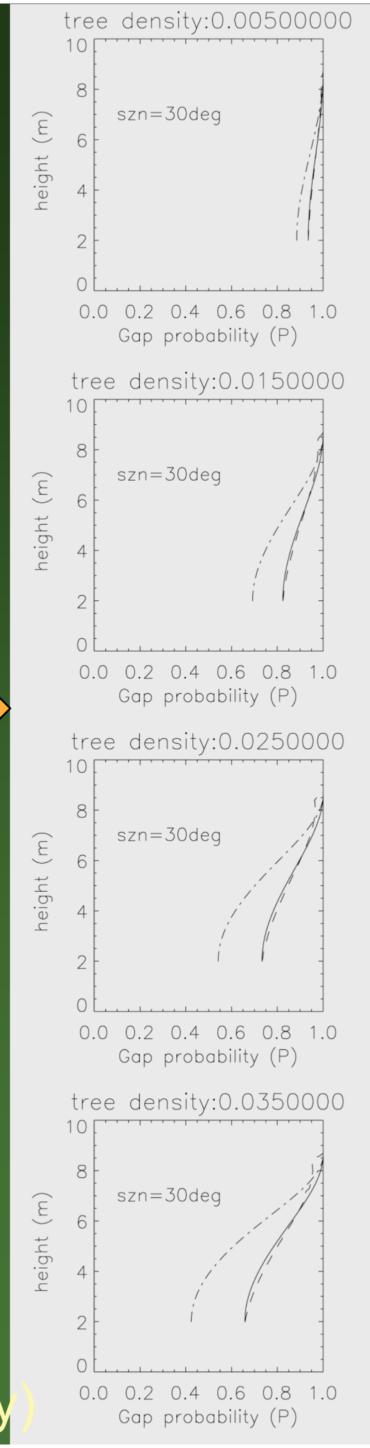
Cover change

Canopy radiative transfer for changing vegetation structure

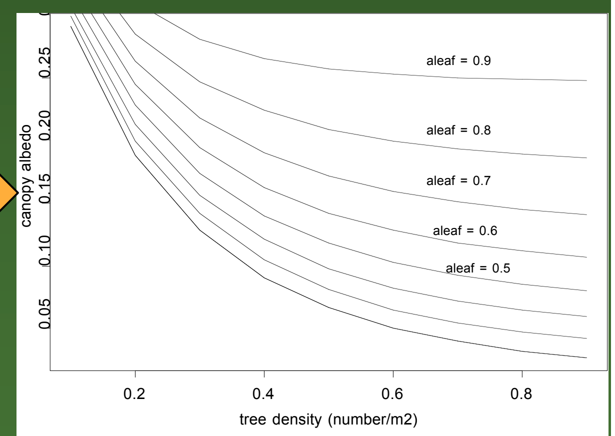


GORT (Ni, et.al., 1999) ellipsoid crowns and gap probabilities

Clumped Beer's law
f(ellipticity, foliage density)



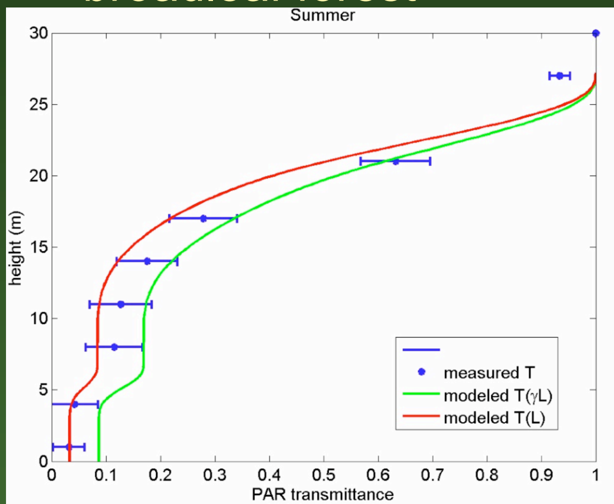
- Vertical light profiles tested on boreal needleleaf forest, broadleaf deciduous, eucalyptus and being coupled to Ent biophysics
- Albedo tested on above, to be tested against MODIS albedoes



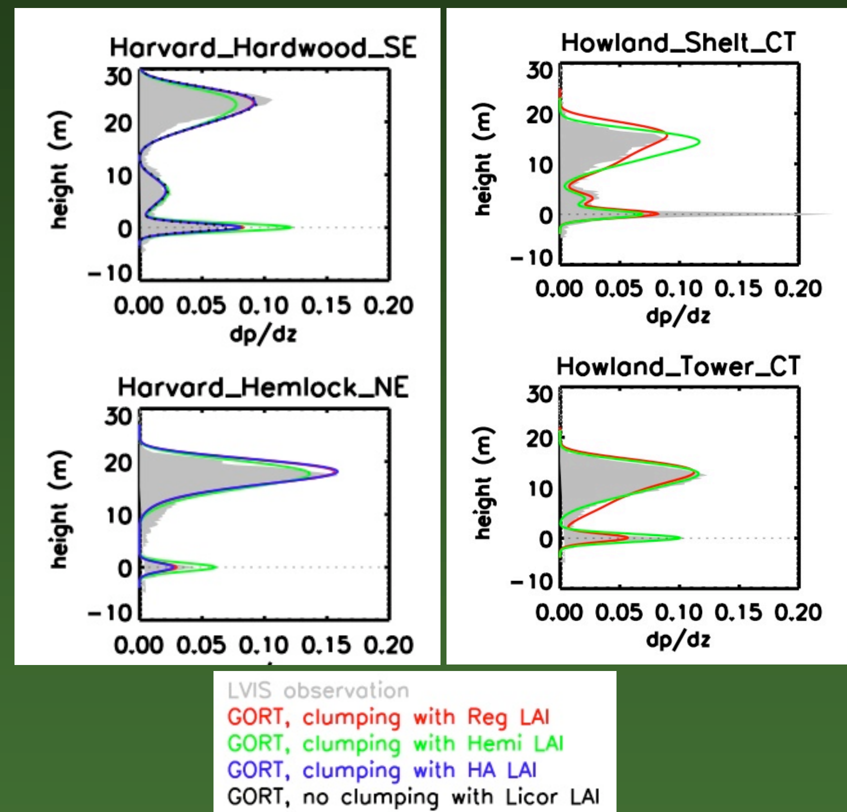
Canopy albedo

Canopy radiative transfer - field tests

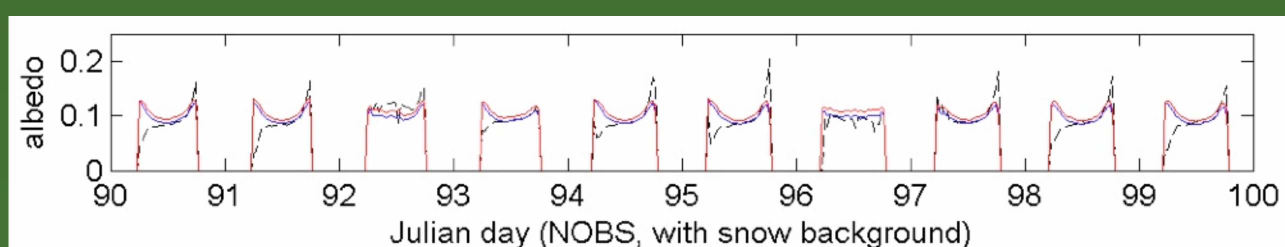
PAR transmittance
broadleaf forest



LVIS Lidar foliage profiles - broadleaf



Albedo - boreal spruce



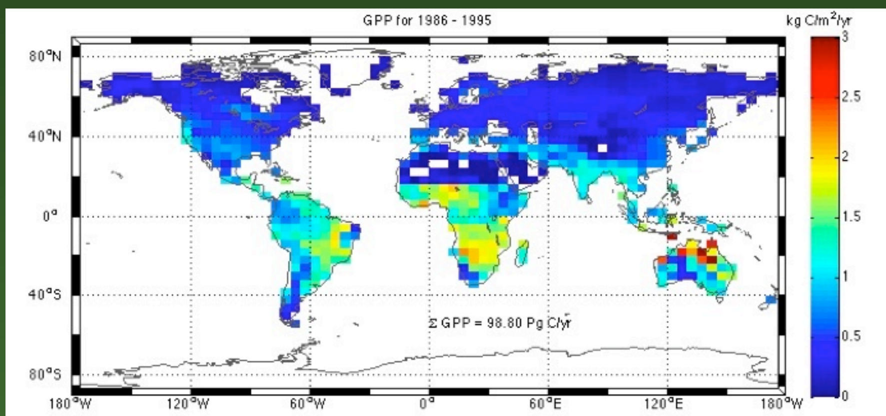
black--field value, blue--Full GORT, red—ana GORT

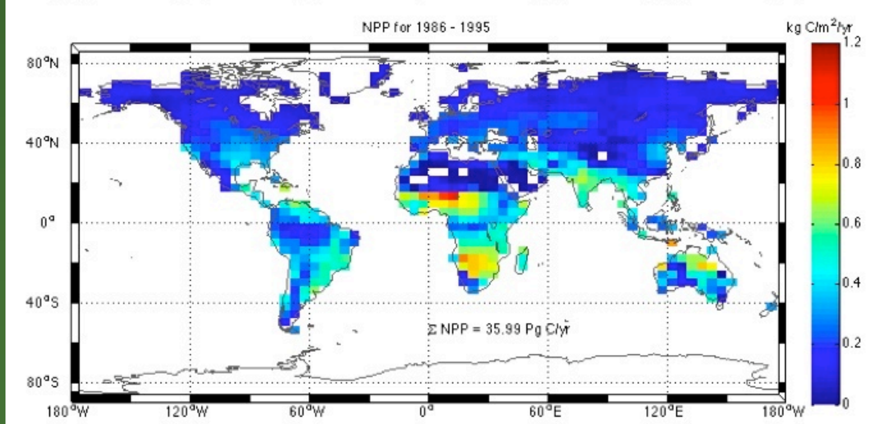
Ent global off-line preliminary runs GSWP2 1986-1995 forcings

NPP = GPP - Rauto

NEE = NPP - Rsoil

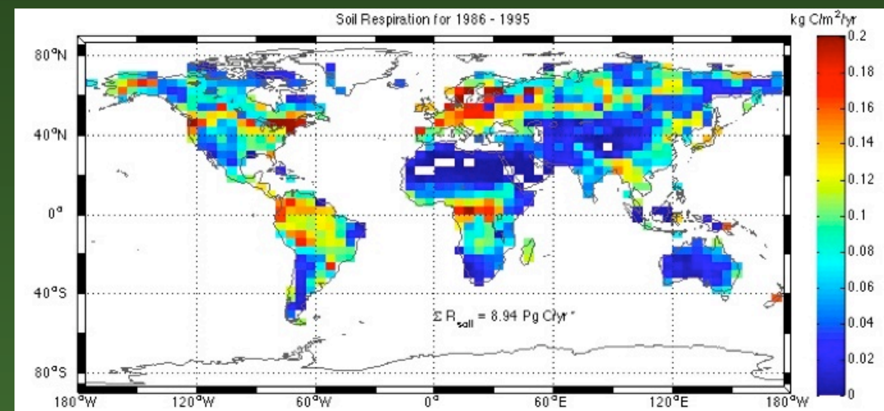
GPP

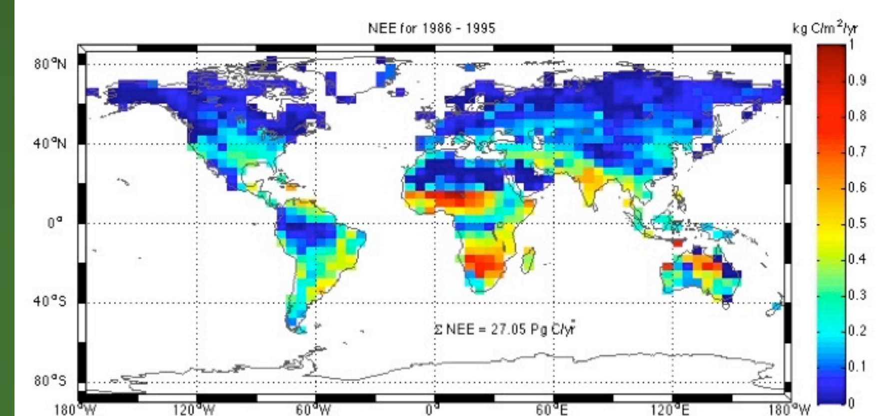




NPP

Rsoil





NEE

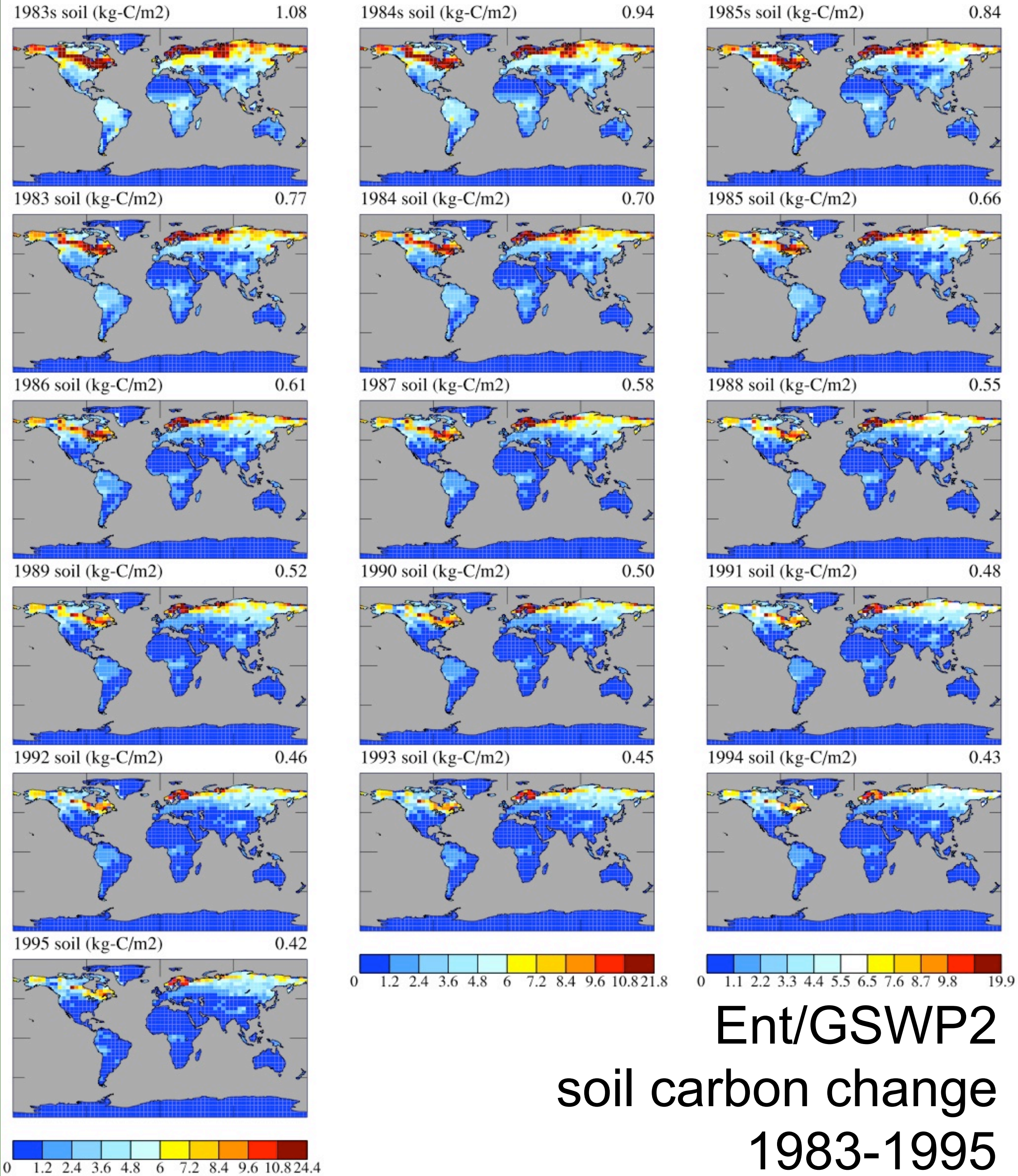
Ent soil carbon spin-ups at Fluxnet sites

Comparison of Ent model to previous models

kg-C/m^2

PFT	*no explicit depth structure*				*with explicit depth structure*						
	(implicitly 0–30 cm)				0–30 cm			30–100 cm			
	fixed Q10	arctan	linear	**obs1**	fixed Q10	arctan	linear	fixed Q10	arctan	linear	**obs2**[4]
C3 grassland	2.8	1.5	7.5	**6.0**[1]	1.4	0.8	3.4	1.4	0.7	3.9	**3**
Deciduous forest	8.6	2.1	6.0	**6.7**[2]	4.8	1.3	3.5	3.5	0.8	2.4	**4**
Savanna	2.8	1.4	6.1	**4.6**[1]	2.0	1.0	3.8	0.8	0.3	2.0	**3**
Evergreen needleleaf forest	58	18	45	**4–15**[3]	42	14	33	16	4	11	**16**

Kharecha et al., in prep



Ent/GSWP2
soil carbon change
1983-1995

Losses of Soil carbon (top 30 cm) during GSWP2 run from initial ISRIC-WISE:

--temperature & moisture responses

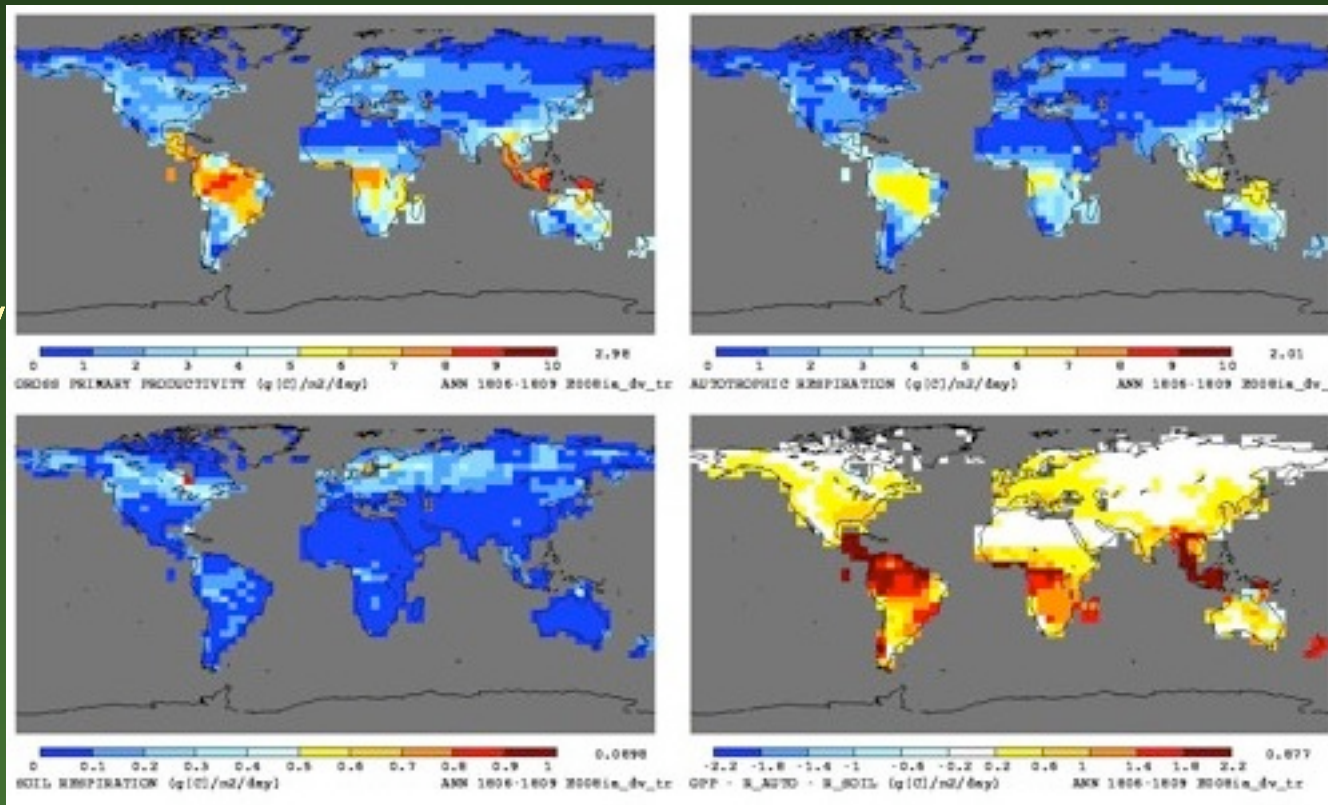
-- litterfall?

GISS GCM coupled runs

Land Carbon Fluxes: Net sink 41.6 Gt-C/yr (Pg-C/yr)

GPP = Gross primary productivity

R_auto = Plant respiration



R_soil = Soil respiration

NEE = GPP - R_auto - R_soil

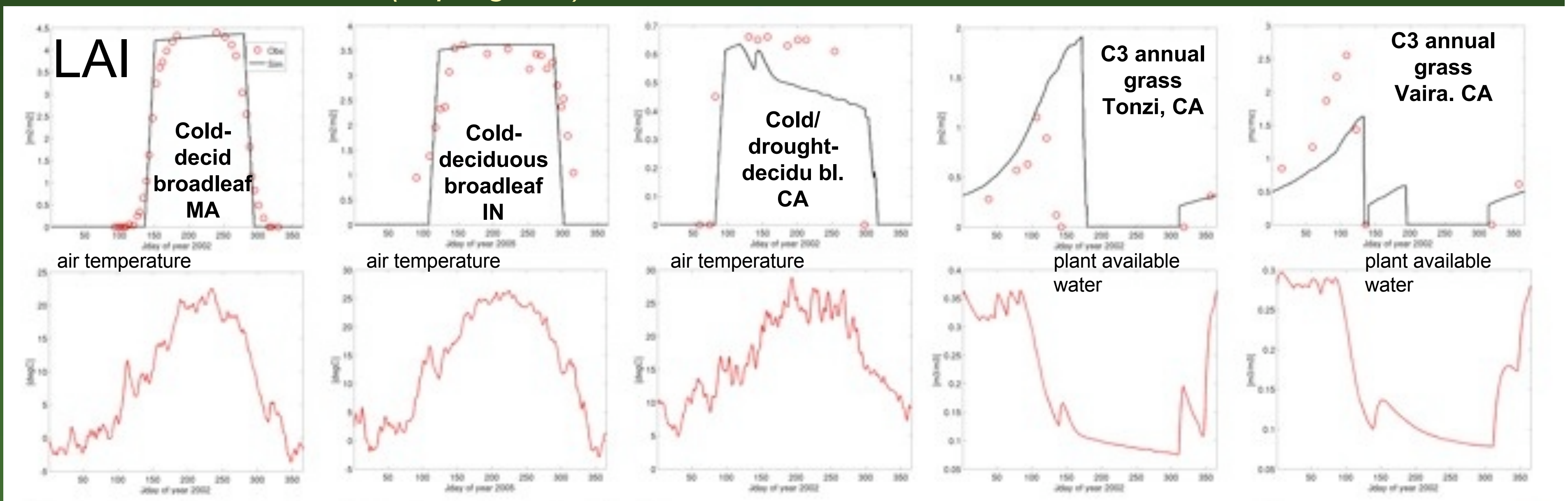
Interactive CO_2: land currently a net sink at pre-industrial climate

Fix: phenology, new land cover specs., allocation/litter scheme, etc.

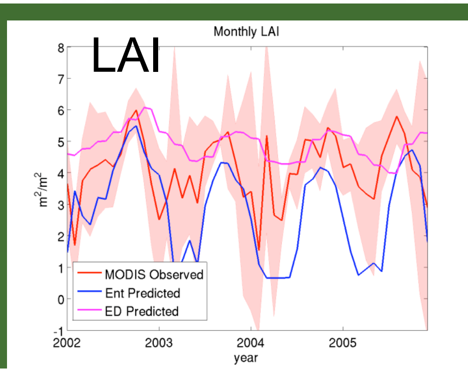
Phenology - Site Evaluation

- Temperate – Harvard Forest, Morgan Monroe State Forest
- Mediterranean – Vaira Grassland, Tonzi Savanna
- Boreal - Hyytiala pine forest, Finland
- *Tropical – Tapajos National Forest (in progress)*
- *Tundra - Barrow (in progress)*

November:
Tundra then
Global off-line tests

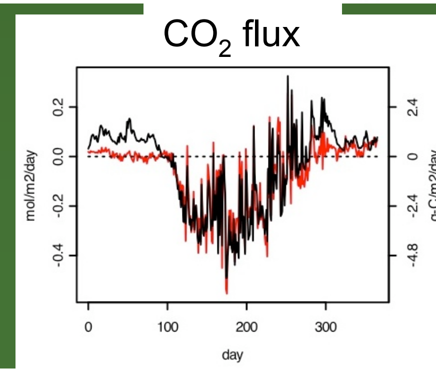


Tropical rainforest Amazon



Boreal pine forest frost hardening, Finland

Red - measurements
Black - Ent



Ent HOW-TO

Demo: cvs checkout GISSClim

X11 Applications Edit Window Help (34%) Wed 14:52 PM

xterm

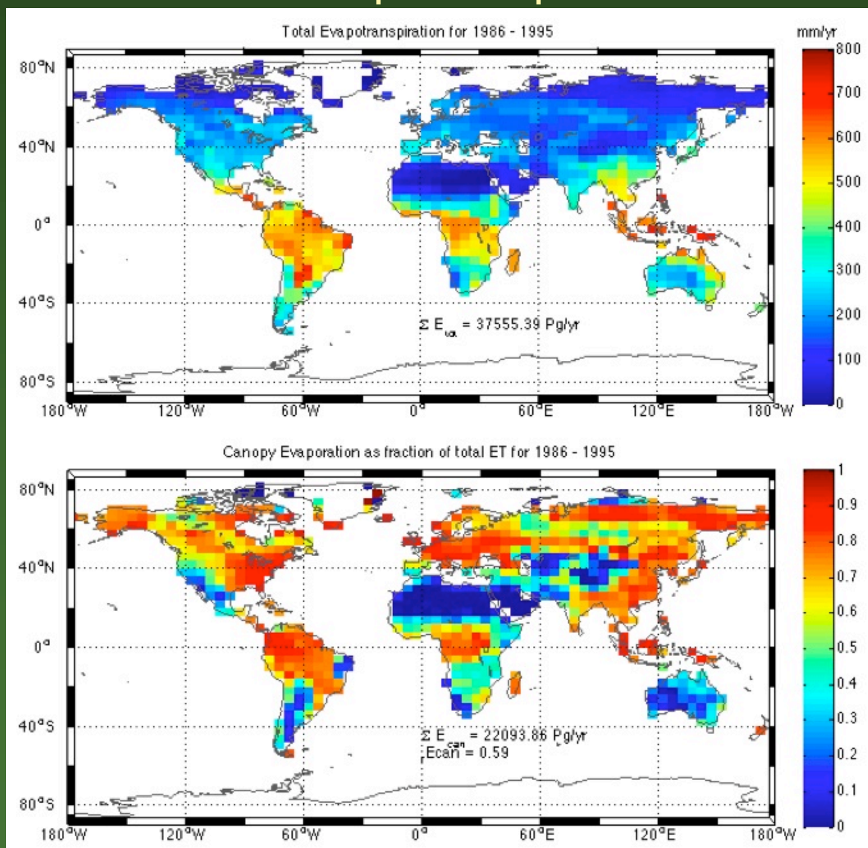
```
[nancykiang:Code/GISSclim/GISSClim] nkiang% ls
CVS             WorkSpace       arch            decks           include         mod             scripts         src
[nancykiang:Code/GISSclim/GISSClim] nkiang% ls *
CVS:
Entries         Repository      Root

WorkSpace:
CVS                     Makefile                README_Entstandalone    r_ent_fbb.mk            r_ent_fbb_SGI.mk        r_lsm_ent_fbb.mk        r_lsm_ent_fbb_quark.mk

arch:
CVS             Rules.make      base.mk

decks:
CVS                     lsm_standalone.R

include:
CVS             rundeck_opts.h

mod:
CVS             README          mpi_defs.h

scripts:
CVS                     comp_mkdep.pl           ent_copy_forcings       ent_gcmdoc.pl           pproc_dep.pl            sfmakedepend

src:
CVS                     Ent_standalone          drivers                 giss_LSM                main_ent.f              shared
Ent                     Makefile                foo                     giss_LSM_standalone     main_lsm.f
[nancykiang:Code/GISSclim/GISSClim] nkiang% cd src
[nancykiang:GISSclim/GISSClim/src] nkiang% ls *
Makefile        foo             main_ent.f      main_lsm.f

CVS:
Entries         Repository      Root

Ent:
#canopyradiation.f#             Makefile                        disturbance.f                   ent_pfts_ENT.f                  phenology.f
#canopyspitters.f#              README                          ent.f                           ent_prescribed_drv.f            reproduction.f
CVS                             WorkSpace                       ent_ENTveg.f                    ent_prescribed_updates.f        soilbgc.f
FBBpfts.f                       biophysics.f                    ent_GISSveg.f                   ent_types.f                     util.f
FBBpfts.f.~1.12.~               canopyradiation.f               ent_const.f                     entcells.f
FBBpfts_ENT.f                   canopyspitters.f                ent_mod.f                       f90_interface.m4
FBBpfts_ENT.f.~1.8.~            canopyspitters.f.~1.21.~        ent_mod.m4f                     growthallometry.f
FBBphotosynthesis.f             cohorts.f                       ent_pfts.f                      patches.f

Ent_standalone:
CVS             HOW-TO          Makefile        ent_forcings.f  ent_prog.f      entrc.example

drivers:
CVS                     lsm_standalone.f

giss_LSM:
CVS             GHY_COM.f       GHY_ENT.f       Makefile        SNOW_DRV.f      VEG_COM.f       rundeck_opts.h
GHY.f           GHY_DRV.f       GHY_ENT_DRV.f   SNOW.f          VEGETATION.f    VEG_DRV.f

giss_LSM_standalone:
CVS                     Makefile                domain_decomp.f         drv_gswp_force.f        lsm_standalone.f        mmap_utils.c            sys_usage.c

shared:
CONST.f         CVS             Makefile        PARAM.f         PARSER.f        SYSTEM.f        TRIDIAG.f       UTILDBL.f
[nancykiang:GISSclim/GISSClim/src] nkiang%
```

Warning: GCM/GHY biases

Temperature, soil moisture, Cloudiness/radiation

Too much canopy interception: How GCM uses canopy conductance.
- Also adversely affects GPP.

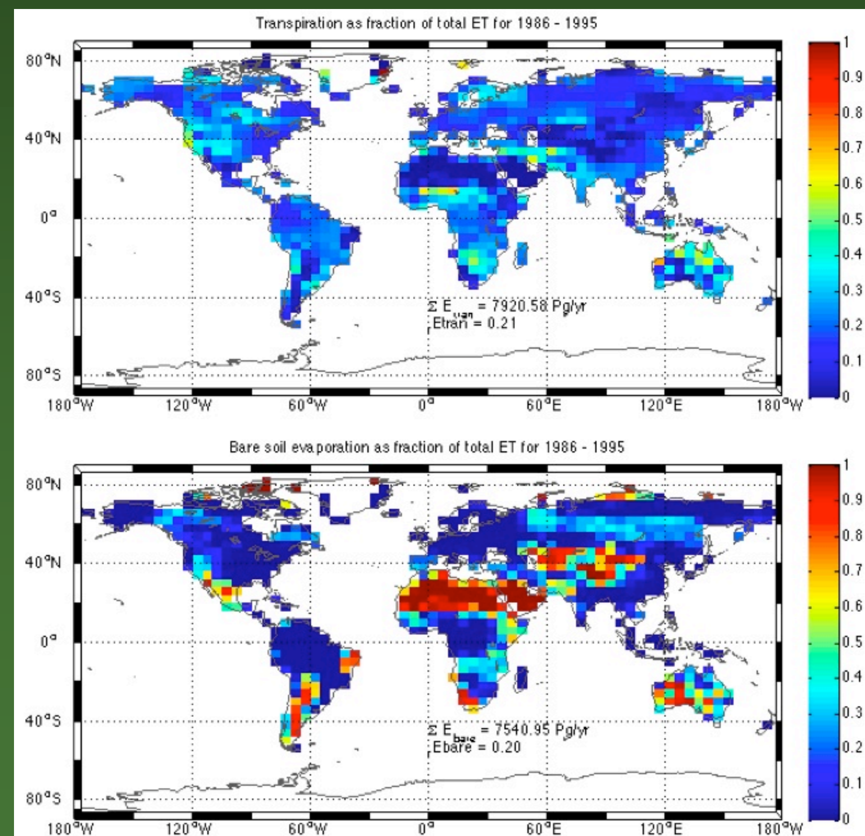
TOTAL Evapotranspiration



Canopy interception fraction

Off-line GSWP2 runs with GISS ground hydrology

Transpiration fraction



Soil evaporation fraction

Acknowledgments

Donald Anderson
NASA Earth Science, Modeling, Analysis & Prediction
GISS Global Model Development Grant (NASA MAP)
Ent Dynamic Terrestrial Ecosystem Model Grant
(MAP/04-116--0069)
James Hansen

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